Probing the Gluon Polarization with the Helicity Asymmetry in J/Ψ Production in Longitudinally Polarized p+p Collisions at $\sqrt{s} = 200$ GeV

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Abstract. Understanding the contribution of the polarized gluons to the proton spin is one of the key steps toward resolving the nucleon spin crisis. At RHIC energy, heavy quark production is dominated by gluon-gluon interaction, thus measurements of A_{LL} of the heavy flavor production in the polarized p+p collisions will allow us to directly access the polarized gluon distribution. During the recent polarized p+p run, the PHENIX experiment has collected about $3.8\ pb^{-1}$ data with longitudinal beam polarization of 47%. The PHENIX forward muon spectrometers measured J/Ψ production though the $J/\Psi \to \mu^+\mu^-$ decay mode at a rapidity range $1.2 < |\eta| < 2.4$. We present the latest result of the double longitudinal spin asymmetry A_{LL} in J/Ψ production in the polarized p+p collisions at $\sqrt{s} = 200$ GeV

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INTRODUCTION

The striking results from the EMC experiment at CERN[(1)] showed that the total spin of the quarks, contrary to naïve quark parton model expectation, does not account for the total spin of the proton. Over the past 20 years, a large number of polarized lepton-nucleon deep inelastic scattering (DIS) experiments have established that only 10-30% of the proton spin is carried by the quarks and anti-quarks, and the rest of spin must be coming from the gluon spin and the parton orbital angular momentum. One leading possibility is that gluons carry the missing spin and therefore PHENIX has a major goal of measuring the gluon spin-structure function in the proton.

Our current knowledge of the polarized gluon distribution, $\Delta g(x)$, suffers from large theoretical and experimental uncertainties in extraction from the limited polarized DIS results since gluons are charge neutral and do not directly couple to virtual photons at the leading order. The RHIC-SPIN program provides a new tool to directly collide (polarized) quarks and gluons at leading order at high energy. Furthermore, heavy quark production in polarized p+p collision at RHIC energy is dominated by gluon-gluon interaction, and thus providing direct access to the (polarized) gluon distribution in the proton. The double spin asymmetry in heavy quark(onium) production at RHIC is sensitive to polarized gluon distribution in the nucleon:

$$A_{LL} = \frac{\sigma^{++} - \sigma^{+-}}{\sigma^{++} + \sigma^{+-}} \approx \frac{\Delta g(x_1)}{g(x_1)} \frac{\Delta g(x_2)}{g(x_2)} a_{LL}^{gg \to Q\bar{Q}}$$

where $a_{LL}^{gg \to Q\bar{Q}}$ is the partonic level asymmetry calculated in pQCD and is not very small, ~ *O(0.1)*.

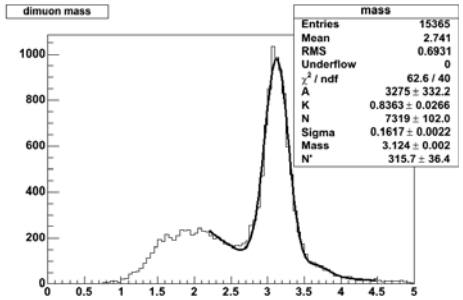

FIGURE 1. Di-muon invariant mass distribution.

EXPERIMENTAL MEASUREMENTS AND RESULTS

In this report we present the results for double longitudinal spin asymmetry in *J/ψ* production in polarized p+p collisions at RHIC. The *J/ψ* has the largest production cross-section among all the heavy quarkonia. The PHENIX experiment has measured *J/ψ* yields through $J/\psi \to \mu^+\mu^-$ channel at forward rapidities ($1.2<|\eta|<2.4$), and determined the double spin asymmetry A_{LL} from:

$$A_{LL} = \frac{1}{P_B \cdot P_Y} \frac{N_{J/\psi}^{++} - R \cdot N_{J/\psi}^{+-}}{N_{J/\psi}^{++} + R \cdot N_{J/\psi}^{+-}}, \quad R = \frac{L^{++}}{L^{+-}}$$

where $N^{++}(N^{+-})$ is the number of *J/ψ* produced in the same (opposite) helicity state *p+p* collisions, and P_B and P_Y are the polarization values of the colliding beams, and *R* is the relative luminosity of different helicity configurations.

During the RHIC polarized p+p run in 2005, PHENIX accumulated 3.8pb^{-1} of integrated luminosity with an average beam polarization of 47%. We used the Level-1 dimuon triggered data sample in this analysis. A single Gaussian fit to the $\mu^+\mu^-$ invariant mass spectrum from the entire data set is shown in Figure 1. An exponential background under the *J/ψ* mass peak is assumed in this fit. Monte Carlo simulation showed the systematic error in measuring $N_{J/\psi}$ from this fit is less than 2%. A global collision vertex range and muon track quality cuts were applied for event selection. The total number of *J/ψ* in the selected sample is 7319±102.0. For A_{LL} calculation, the *J/ψ* yield was extracted for each RHIC store of the beams as the relative luminosity varied significantly in each store, but remained constant within a store. Most of the combinatoric background for $\mu^+\mu^-$ pairs in the *J/ψ* mass region was removed by using like-sign muon pairs subtraction method:

$$N_{J/\psi} = N(\mu^+\mu^-) - N(\mu^+\mu^+, \mu^-\mu^-)$$

This leaves about 8% background for $N_{J/\Psi}$ within the dimuon mass window of $M_{J/\psi}\pm 2\sigma$, estimated from the above fitting method.

The raw asymmetry was calculated store by store for two p_T bins. The background asymmetry was determined using the $\mu^+\mu^-$ pairs within $2<M_{\mu\mu}<2.5$ GeV, and $\mu^+\mu^+$, and $\mu^-\mu^-$ pairs within $2.6<M_{\mu\mu}<3.6$ GeV in the invariant mass spectrum from Figure 1. The average background contribution is estimated to be -0.0041 ± 0.018. Taking into account of the contributions from background, the final results of $A_{LL}^{J/\Psi}$ is calculated given by,

$$A_{LL}^{J/\Psi} = \frac{A_{LL}^{incl} - r \cdot A_{LL}^{BG}}{1-r}$$

$$\delta A_{LL}^{J/\Psi} = \frac{\sqrt{(\delta A_{LL}^{incl})^2 + r^2 \cdot (\delta A_{LL}^{BG})^2}}{1-r}$$

Figure 2 shows the final A_{LL} results for two $<p_T>$ bins, 0.82 and 2.3GeV, along with the theoretical predictions[2,3] from different J/ψ production models. The p_T averaged asymmetry is $-0.032\pm0.065(stat)$.

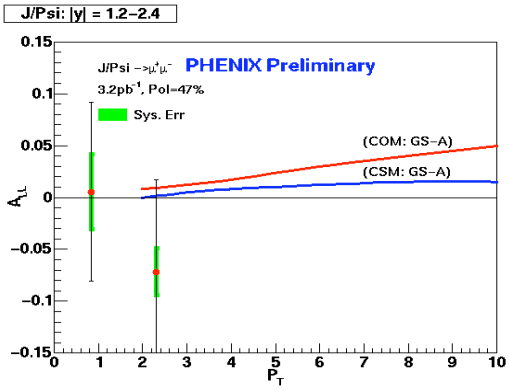

Figure 2. PHENIX preliminary results for J/ψ double spin asymmetry.

SUMMARY

The longitudinal double spin asymmetry in J/ψ production has been measured for the first time at $\sqrt{s} = 200$ GeV at RHIC. Currently the results are statistically limited to distinguish various gluon polarization models. In the future, the expected 320pb^{-1} delivered luminosity with improved beam polarization of 70%, will improve the statistical Figure of Merit ($P^4 \cdot L$) of the double spin asymmetry by a factor of ~100, and could help us to understand the gluon contribution to the proton spin.

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